Squaring the Long View: Regulatory, legal and geologic considerations for future research agendas for CCS

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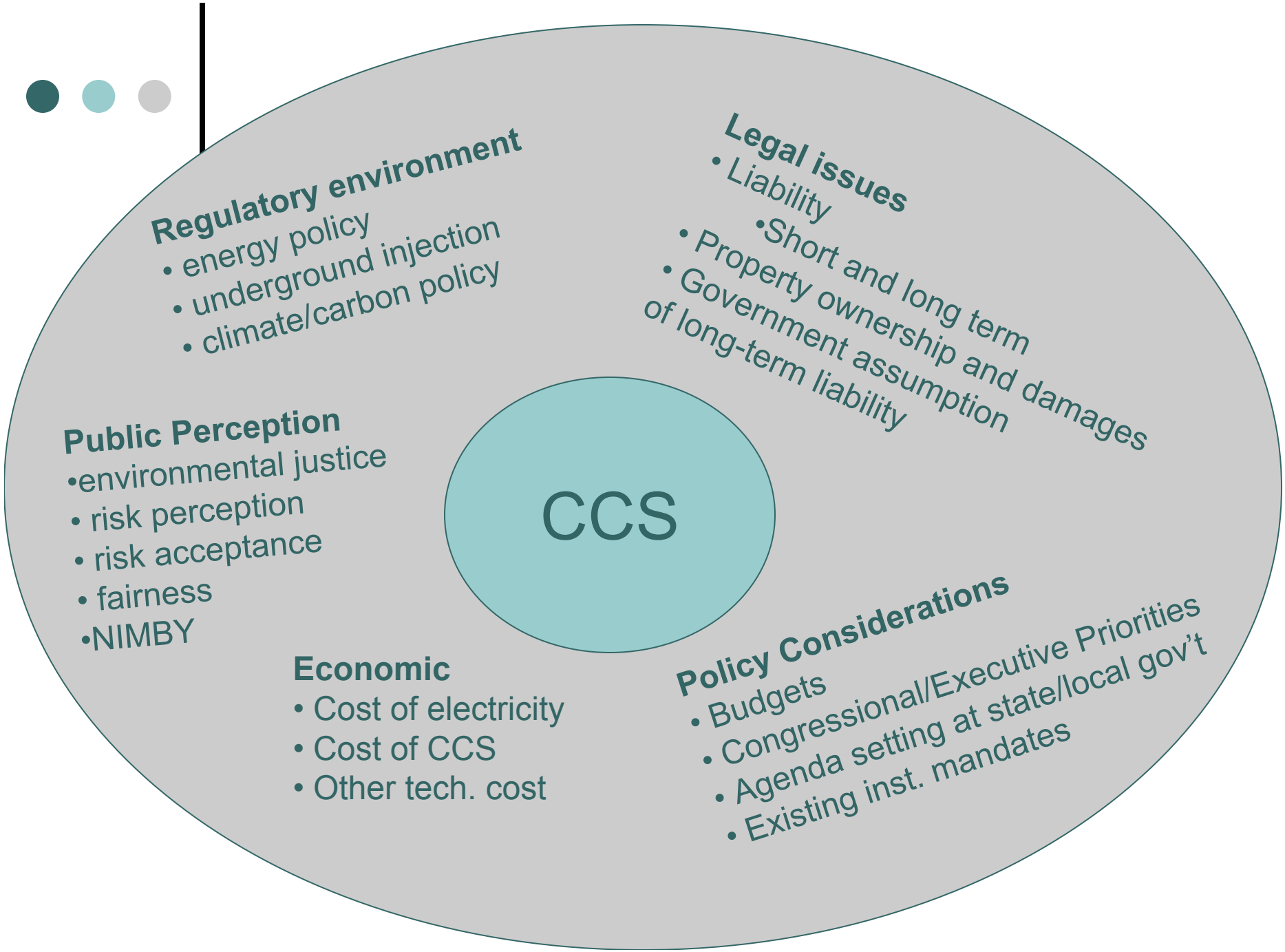
Avoiding Mr. Toad's Wild Ride:

Targeting Risk to Fill Regulatory and Legal Gaps

Dialogue on technology risks embedded

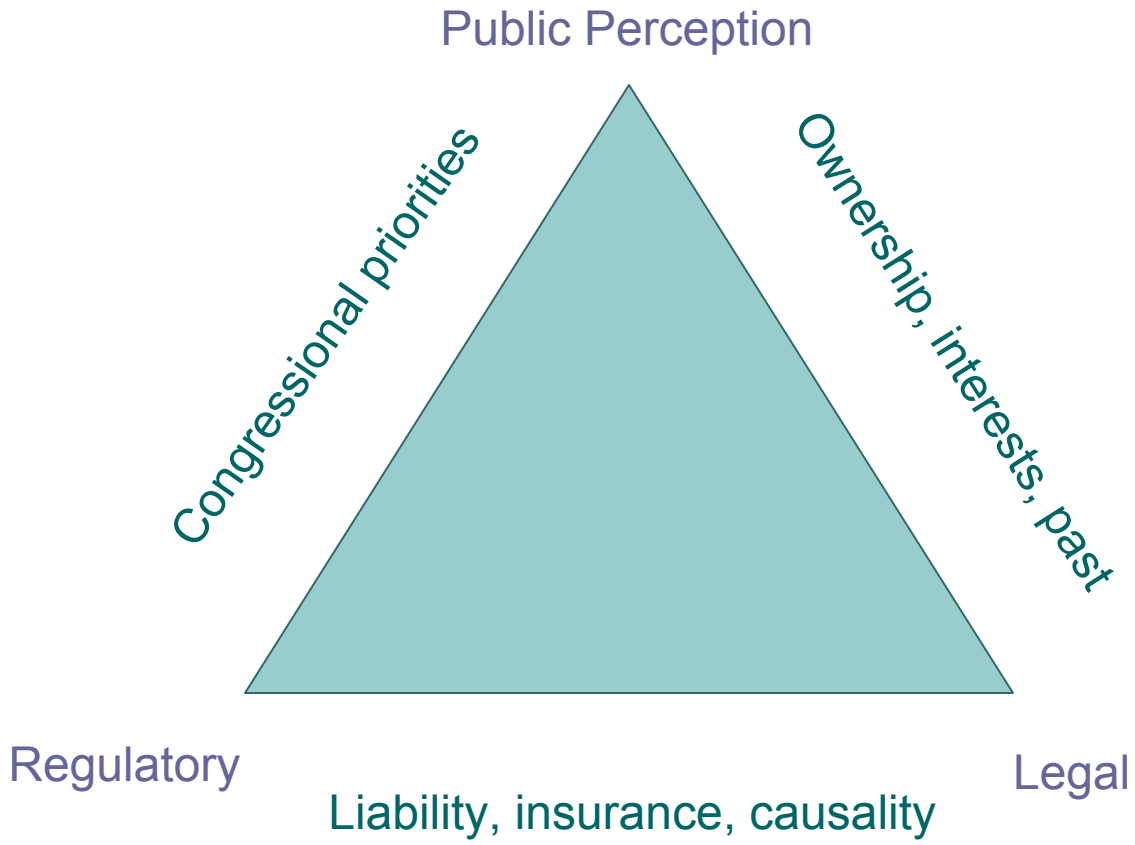
- Main points for this talk:
  - CCS will be deployed within a complex regulatory, legal, and political world
  - Technologies have stumbled: GMO's, nuclear energy, stem cell research, biotechnology
  - Research must be focused for key questions for deployment
  - Questions raised by legal and regulatory systems crucial for eventual project deployment
    - Aim: to bound risk and uncertainty
    - Well leakage and water contamination remain key risks


Regulatory environment
• energy policy
• underground injection
• climate/carbon policy
Legal issues
• Liability
•Short and long term
• Property ownership and damages
• Government assumption of long-term liability
Public Perception
•environmental justice
• risk perception
• risk acceptance
• fairness
•NIMBY
CCS
Economic
• Cost of electricity
• Cost of CCS
• Other tech. cost
Policy Considerations
• Budgets
• Congressional/Executive Priorities
• Agenda setting at state/local gov't
• Existing inst. mandates

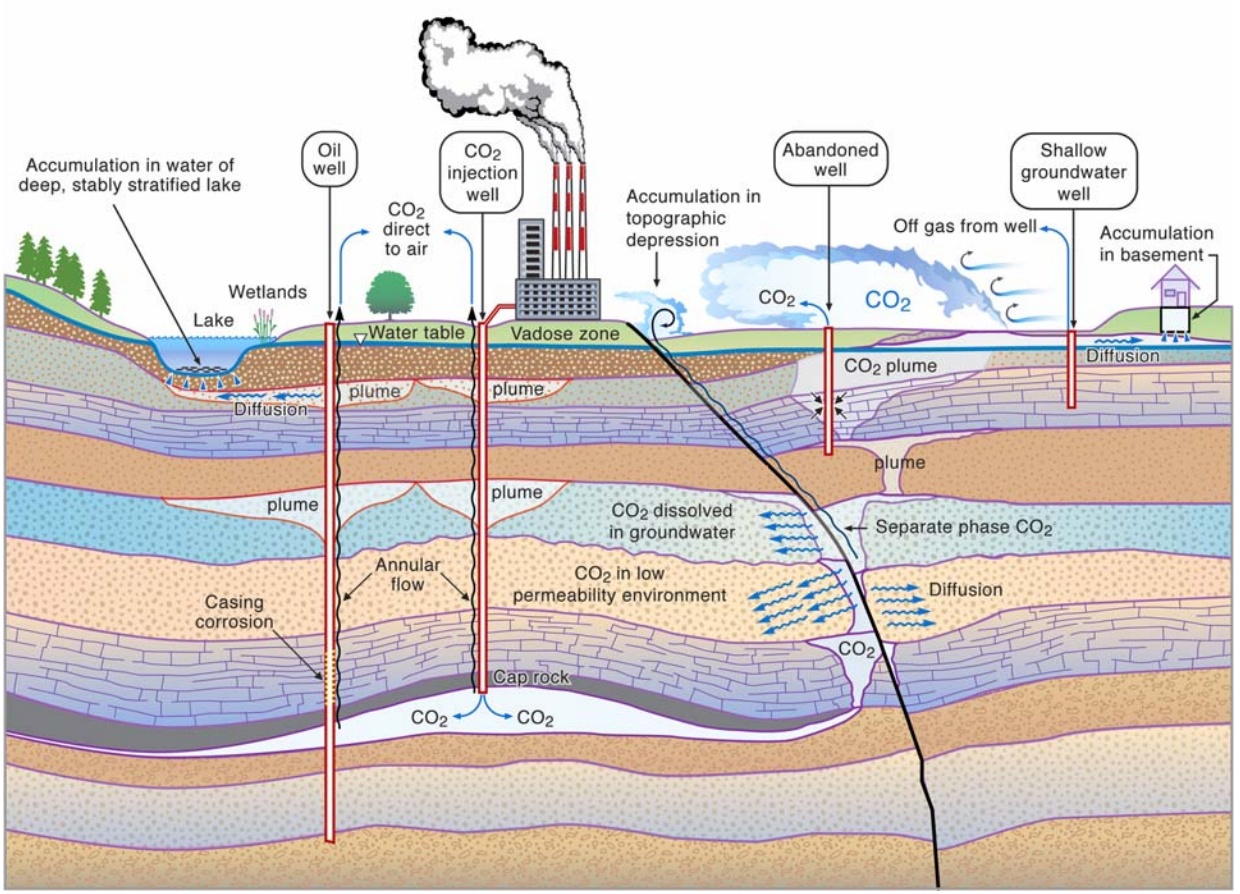
Structure of talk

- Key research questions raised by regulatory and legal systems
- Value in bounding of analysis
- Examples of well leakage and groundwater contamination
- Future research considerations

Interactions between regulatory, legal, and public perception



Regulation and liability tied to risk, linked to SITING



Source: Benson and Hepple, 2004

Leakage in subsurface

- Potential to harm hydrocarbon resources
  - Regulations governing injection practice to protect resources
  - Liability in some states from inadvertent harm from EOR, not in other states
- Potential to harm groundwater resources
  - Liability established, dependent upon jurisdiction
  - Directly (metals mobilization, organics mobilization)
  - Indirectly (displacement)**
- Induced seismicity** (depends upon type of stress regime in formation)
  - Prescriptive management through limits in injection pressure

** could be difficult to prove causality in court

Seepage to surface

- Through wells
  - Regulations governing abandonment and plugging
  - Liability regimes based upon damages
  - Need to understand bounds of leakage
    - 100 t/day at Crystal Geyser
    - 11,000 t/day at Sheep Mountain
    - Risks appear manageable in both cases
  - Abandoned wells
    - One field analysis found ~20% of wells not marked upon map or not correctly locate
  - We have the technology to reduce risk and remediate
    - Aeromagnetic surveys for well location verification
    - Question of cement longevity
- From faults
  - Natural analogs abound
  - Technologies for health risk mitigation

Current regulations not adequate

- CCS Goal: Keep very large volumes of a buoyant fluid underground for long time periods
  - Risks: leakage and subsurface resource harm
- UIC Goal: Do not contaminate USDWs (keep injectate from USDWs)
- Siting
  - No seismic requirements or protocos
  - Relies heavily on publicly available data and well specific data; not comprehensive enough
  - Small Areas of Review (zone of endangerment not always used)
  - No local or regional modeling (only for hazardous waste)

Where is the liability?

- TORT
  - Production/Generation
    - Well understood
  - Transport
    - Understood, but KinderMorgan isn't building more pipelines, changes in property of CO_2 and associated liability
  - Injection *** (Trespass, nuisance, strict?)
    - Handled by existing frameworks, but possibly not for CO_2 unique risks
      - Hydrocarbon
      - Groundwater and leakage
      - Displacement and seismicity (proving causal link more difficult)
      - Essentially cluster around pre-existing property-rights
  - Long term storage***

Liability

- CLIMATE
  - Premature leakage to surface
    - Contract liability
    - Credit value reduced
  - Mechanisms for managing
    - Compensation fund
    - Abandoned wells program
      - …if it worked…
  - Liability for all CO_2 in subsurface, accounting credit for CO_2 injected – energy penalty
  - Importance of cross-border issues
    - State and national jurisdictions
  - Liability in case of non-injection (field work over)

Liability: Location matters

- “The magnitude of the danger is affected both by the probability that the fluid will escape and by the gravity of the resulting injury if it does escape” (Keeton, 1959)
- Siting is key consideration
  - Hydrocarbon damage
  - Importance of groundwater resources
  - Populations affected by leakage
    - Environmental justice considerations
  - Ecological sensitivity
  - Likely potential resource damages based upon actual economic harm
    - What is groundwater worth? Does taste matter?

Legal Considerations for Siting

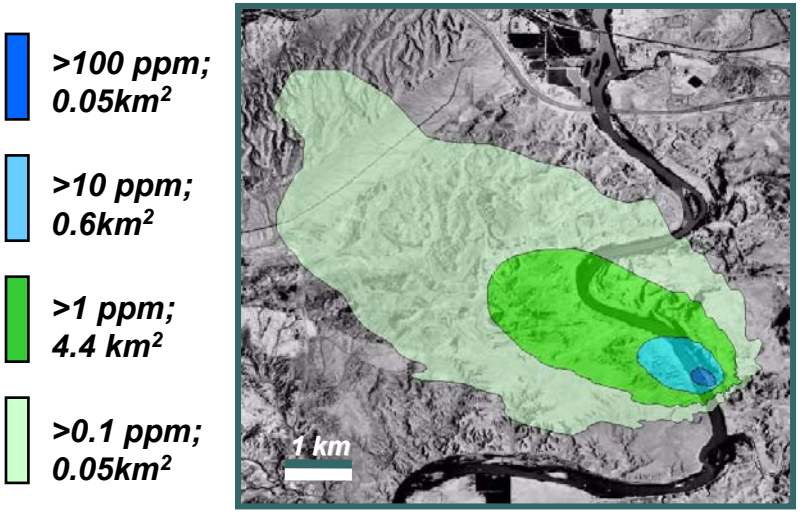
- Tort and contract law (trespass, nuisance, strict liability for abnormally dangerous activities)
- Difference between
  - "first generation" EOR-linked projects
    - Hydrocarbon ownership extraction liability regime
    - What happens when EOR becomes sequestration?
  - "second generation" projects within saline aquifers– different legal framework
    - Subsurface rights controlled by surface owner
    - Federal lands attractive….
- State jurisdictions key
  - Possibly driving siting favorability

Research needs for regulatory and legal regimes

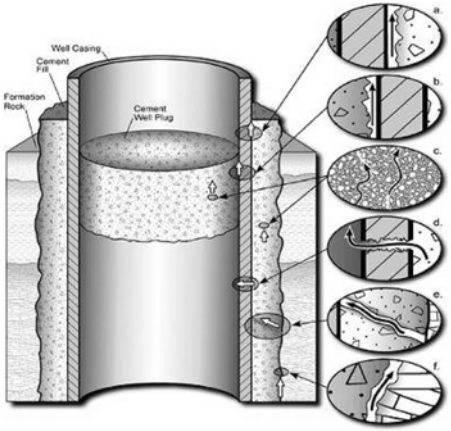
- Damage to groundwater resources
- Leakage to surface
- Long-term storage security
- Operational concerns
- Integrating risk of different sites for liability and regulation

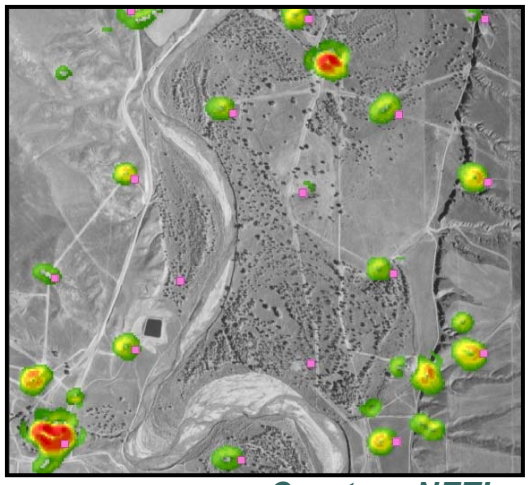
Bounding constraints: abandoned well leakage

- Crystal Geyser
  - 3-10 tons per eruption
  - ~11,000 tons/year
  - Changes over time
  - Rapid dispersion and mixing
- Sheep Mountain
  - Blow out for 17 days
  - 7-11,000 tons/day
  - ~200,000 tons (roughly emissions from ~ 12 days of a 1GWe coal-fired power plant)
  - Remediation executed, well controlled



Bounding information informs science & management choices

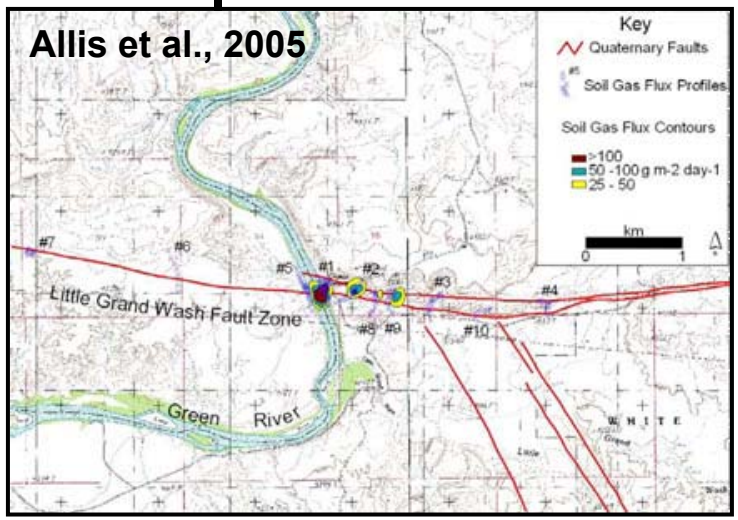


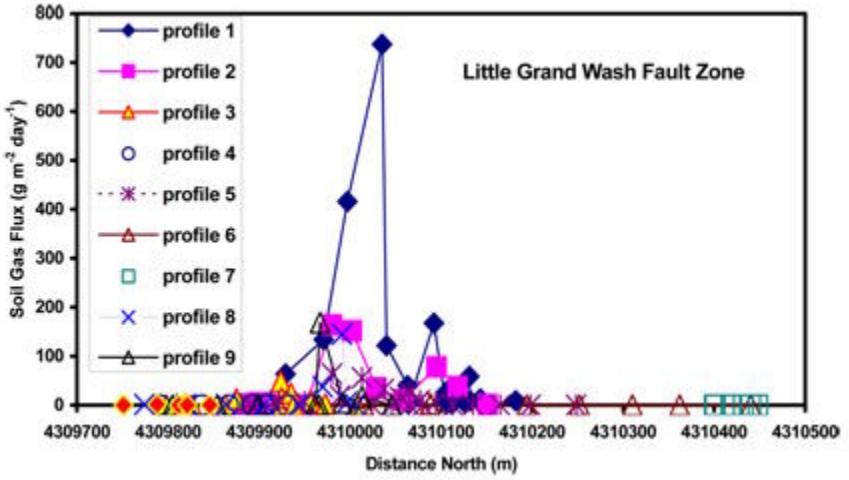


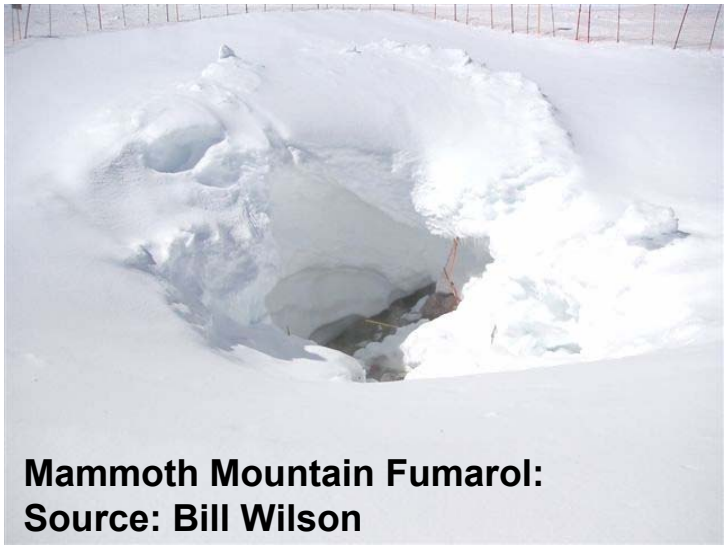
Courtesy NETL

- Process perspective
  - Many possible failure modes
  - Geochemical & geomechanical risks
  - Uncertainty in setting
- Management perspective
  - Tools to find abandoned & orphaned wells
  - Many technologies to close & recomplete
  - Incremental cost

Faults more difficult systems



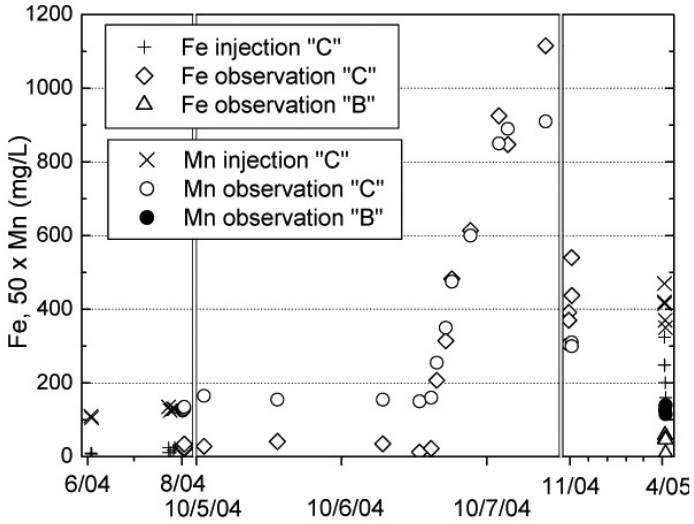


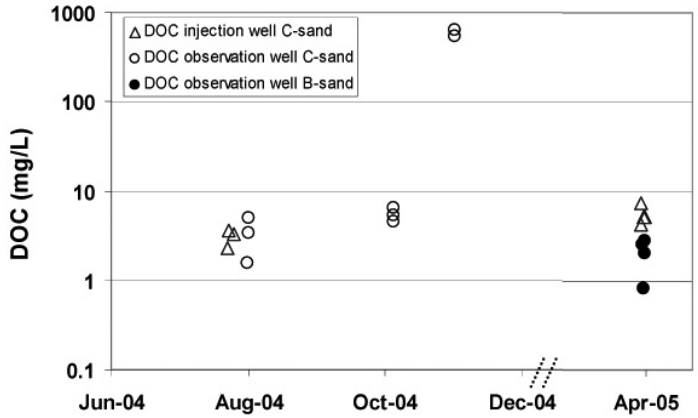


Mammoth Mountain Fumarol:
Source: Bill Wilson

- Rate and magnitude questions
  - Appear smaller than wells
  - More episodic; larger potential range of response
  - Non-linear, complex systems
- Management perspective
  - High value to targeted science
  - Mitigation options less clear

Water quality considerations: CO_2 effects on shallow aquifers

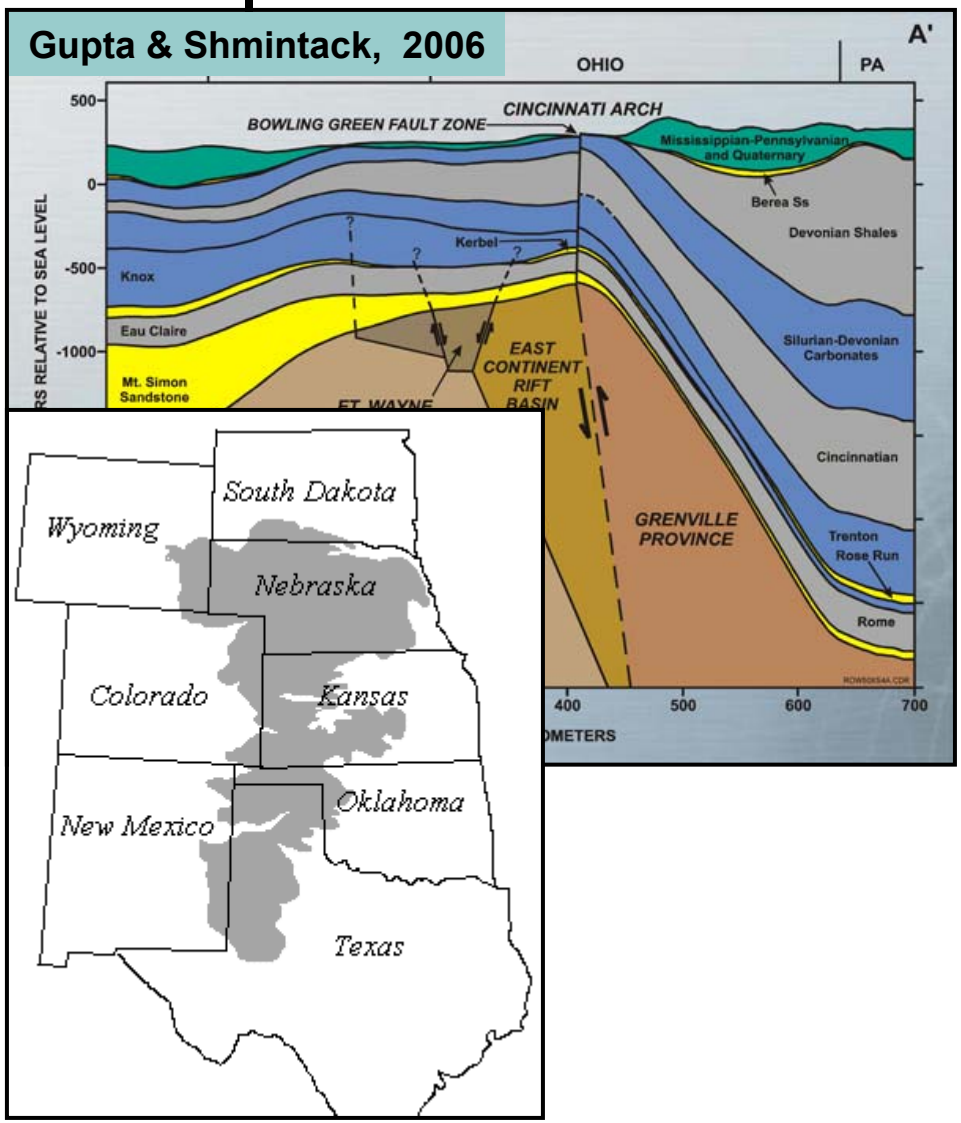




- Frio pilot (U-tube samples)
  - High dissolved metals & organic carbon
  - Metals came from rock volume (mineral coatings)
- Implications of native rock CO_2 interaction
  - Difference in carbonate and siliciclastic systems
  - Kinetics vs. buffering potential
- Importance of bulk and trace aquifer composition

Kharaka et al., 2006

Water quality considerations



- Research & process perspective
  - Need to understand range of potential effects (Fe vs. As)
  - Need for experiments on most important shallow aquifers
- Management perspective
  - Science to quantify risks: rate and concentration bounding terms
  - Potential mitigation/ treatment strategies

Decision driven risk characterization

- Basic premise: risk characterization (and research) needs to be geared towards deployment needs
  - Driven by regulatory, legal and public perception demands
  - Leakage, water quality (direct and displacement), remediation
  - Development of basic “sniff test” metrics (too much information = NO)
  - Iterative nature of activity for new technology
- Role of pilot and large scale basin characterization helpful to bound risks and begin to integrate knowledge within institutions
- Scientific foundation as input to support public decisions
- DO research that is relevant for developing regulatory, and legal, social and political parameters with goal of appropriate deployment

Conclusion : Easy, basic bounding research questions can reduce uncertainty of regulatory/liability concerns

- Distance CO_2 pool (pressure influence) will spread
- Affects CO_2 on drinking water/ ag water
  - In different formations
  - Directly and indirectly (e.g,, displacement)
  - Mobilizing other in/organic constituents
  - Within old plumbing systems
  - DOES THIS EVER COMPROMISE DRINKING WATER STANDARDS? WATER TASTE?
- Amount of CO_2 that can leak
  - From abandoned wells
  - From range of faulting zones
- Remediation of leakage
  - To groundwater
  - To surface


AMELIA

Creating large and legal sequestration reservoirs

- Subsurface property rights (to void space) largely found to be held by surface owner
- Challenge: Create large and legal formations for sequestration
  - Oil and gas production: Unitization
    - making injection efficient, ease of creation dependent upon jurisdiction
    - protection from liability arising from damage to hydrocarbon resources
  - Natural gas storage – power of eminent domain from Natural Gas Act of 1938 and state legislation
  - Mechanism needs to be created for GS in saline aquifers
    - Federal lands potentially more attractive

Importance of technology for remediation for liability and regulation

- Essentially changes risk profile if remediation technology is available and affordable

Strict Liability for abnormally dangerous activities

- According to Prosser, Wade and Schwartz covers activities that are dangerous, but necessary
  - " this liability is analogous to negligence per se, but it is not called negligence because a court makes a judgment that value to the community sufficiently great that the mere participation in the activity is not to be stigmatized as wrongdoing in the negligence sense. The activity is simply required to pay its own way, without that stigma, but it does pay with full tort damages, including pain and suffering damages when personal injury is involved" (Schwartz *et al.* p. 704)
- Location important
- Many activities have been found to be abnormally dangerous (oil wells different by jurisdiction, pile driving, crop dusting, fireworks, etc…)

Partitioning of liability

- Many cases found joint and several liability to multiple plaintiffs from nuisance
  - Need to determine which party caused the harm
    - Proportional attribution based upon injection into reservoir
    - Any risk of retroactive liability?
- Within responsible parties
  - In case of damages, need to determine responsibility and potential liability
  - Profile of liability changes over time
    - Operational phase
    - Post-closure phase
    - Long-term closure phase
- Responsibility of government and private parties shifting and evolving over time
  - WHEN?

Public perception studies on CCS

- Most people don't know about this technology yet
  - Opportunity and risk (ocean sequestration cautionary tale)
  - Public perception of risk not based upon rational and objective measures
  - Concerns: leakage, property values, water
  - NUMBY– "Not Under My Backyard"
  - Location: key in siting
    - especially important for first few projects
    - Perceived fairness
    - Public involvement in siting/permitting?
  - Characteristics of opposition: Local or national
  - Moral considerations: Future generations

Other Liability

- Causation in fact
  - Proximate cause
    - Difficulty in proving induces siesmicity, displacement
- How long can party be held liable for?
  - Longest cases are much shorter than 300 years
- How do intervening causes affect liability (and security/risk profile) over time?
- Vicarious liability– “imputed negligence”

Legal Considerations: Geophysical Trespass

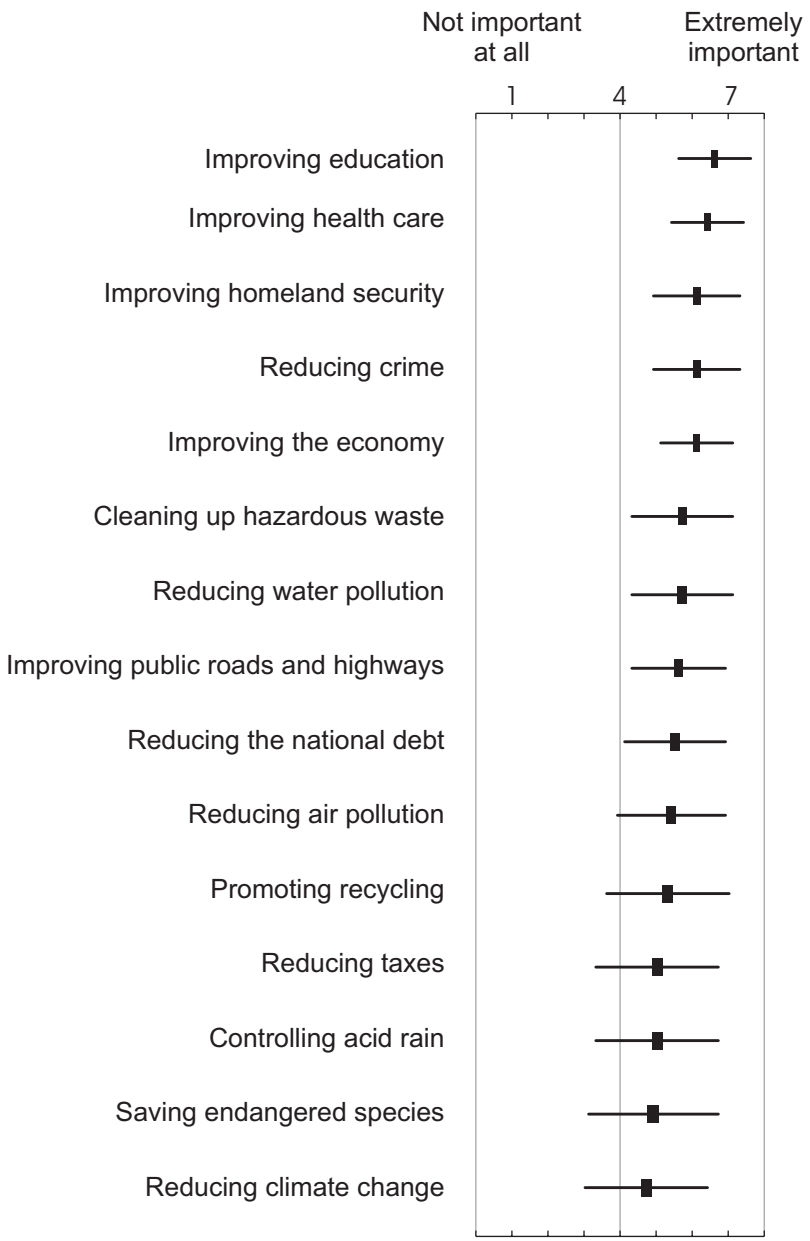
- Liability associated with siting
  - Geophysical trespass
    - Value of lease for hydrocarbon resources
    - Garnering this information is trespass…
  - Challenges in establishing 40 mi^2 reservoir with a .25 AOR and legal geophysical trespass considerations
  - Possibly not such a problem with federal lands or saline aquifers (no case law here)

Role for insurance

- Environmental and general liability
  - Time frame short
- Public assumption of risk and monitoring occur over long term
  - Orphaned well program
- Other models
  - Nuclear industry, vaccine industry
  - Balance of public or private role
- Courts have found role of insurance as a decisional factor in liability
- Key players in future of project deployment

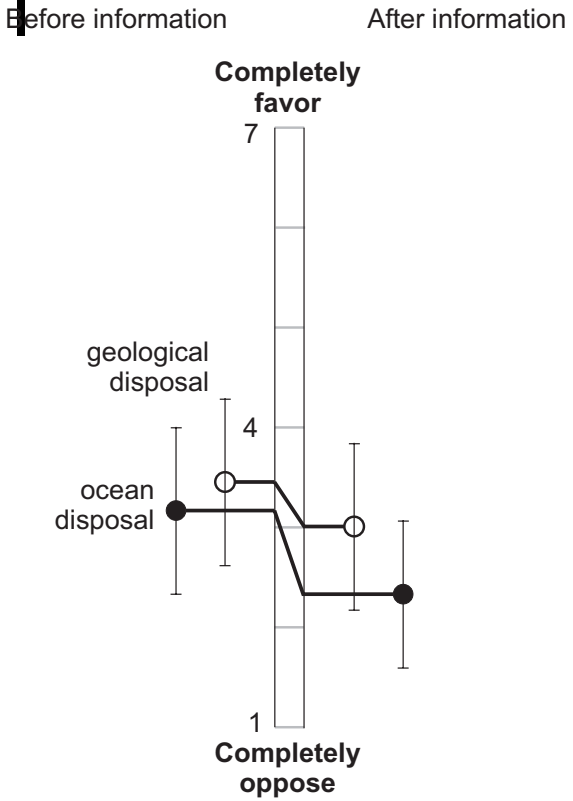
Public perception

- Global benefit with potential local risks
- Media coverage of technology
  - Accidents, past experience with similar technologies
- Perception of risks
  - Expert v. public assessment of risks
  - Prominence of risk
  - Rule of thumb assessments
  - Ethics diminishing over distance
  - Expert trust (coal and oil industry)
  - Probabilit-ish
- Acceptability of technology within larger energy policy context

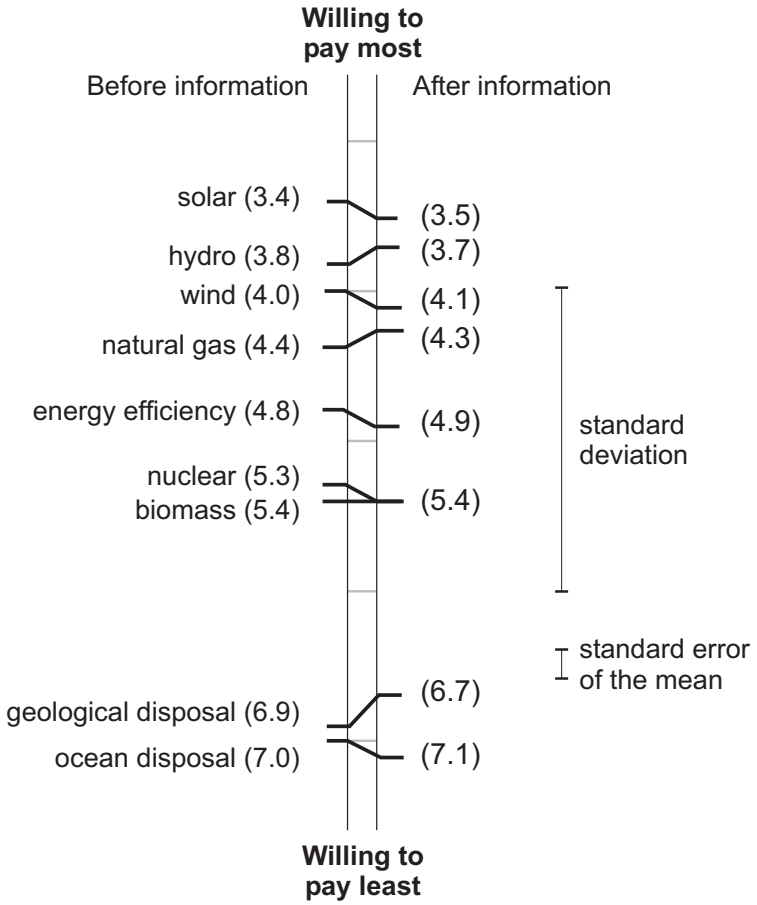


(Palmgren et al. 2004)

A: Rating task



B: Energy service ranking task



(Palmgren et al. 2004)

Regulatory considerations

- Additional information is needed for current framework to meet future regulatory demands
  - Siting
  - *In situ* CO2 behavior
  - Long term performance
  - Long term leakage
- What types of *simple* tests or metrics could be developed to help regulators evaluate projects?
    - Sensitivity and uncertainty methods to bound risk
    - Too much information = NO

Key Legal Considerations

- Liability regimes
  - Long term and *in situ* damage
  - Climate liability and accounting system
  - Public assumption of liability
  - Compensation fund– similar to abandoned wells program adequate?
- Large and legal
  - Oil and gas production -- Unitization – making injection efficient, protection from liability
  - Natural gas storage – power of eminent domain
  - GS in saline aquifers…federal lands potentially more attractive
- Implications/affordability of remediation options on liability regime

Regulatory Considerations for GS

- Protecting public and environmental health and larger climate regime
- Current underground injection managed by EPA's Underground Injection Control Program, authorized by Safe Drinking Water Act
- Focus of regulation
  - Groundwater protection underlies current regulatory framework
  - Operational strategy: Keep harmful substances away from public supplies of drinking water